Al-Farabi Kazakh National university
Syllabus
ChMIZGD 6307; ChMIZGD 6308 - NUMERICAL METHODS FOR GASDYNAMICAL PROBLEMS

Fall semester 2016 - 2017 academic year

<table>
<tr><th rowspan="2">Code of Discipline</th><th rowspan="2">name Discipline</th><th rowspan="2">Type</th><th colspan="3">Number of hours per week</th><th rowspan="2">Number of credits</th><th rowspan="2">ECTS</th></tr>
<tr><th>Lec</th><th>Prac</th><th>Lab</th></tr>
<tr><td></td><td>Numerical methods for gasdynamical problems</td><td>OK</td><td>1</td><td>2</td><td>0</td><td>3</td><td>5</td></tr>
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<table>
<tr><td>Prerequisites</td><td colspan="3">Fluid Mechanics", "Continuum Mechanics", "Differential Equations", "Mathematical Physics", "Thermodynamics", "CFD".</td></tr>
<tr><td>Lecturer</td><td>Yerzhan Belyayev, Doctor PhD</td><td rowspan="2">Office hours</td><td rowspan="2">By timetable of the classes</td></tr>
<tr><td>e-mail</td><td>Yerzhan.Belyaev@kaznu.kz</td></tr>
<tr><td>Telephones</td><td>8 (727) 377-31-93</td><td>Lecture hall</td><td>By timetable of the classes</td></tr>
<tr><td>Course description</td><td colspan="3">Study of CFD specifics in Compressible Flow simulation. Particularly, modeling of discontinuous function (shock waves). Hyperbolic partial differential equation, Euler equations, Riemann problem for Euler equation. Godunov type schemes, TVD, ENO schemes.</td></tr>
<tr><td>The aim of the course</td><td colspan="3">To teach students the basic and modern computational technics in Gas Dynamics, to teach them to understand the basic equations and to solve these equations using numerical procedures. The purpose of discipline is familiarize students with the basic numerical approaches, which are covered with practical examples. Concept of the course is based on the book "Computational Gasdynamics (CGD)" by Culbert B. Laney. As a result of studying the course, students should know the basic system of equations for compressible flows, numerical methods of solution these equations, pros and cons of that numerical methods.</td></tr>
<tr><td>learning Outcomes</td><td colspan="3">Necessary knowledge in the basics of gas dynamics and skills to numerically solve the problems of compressible flows.

General competence:

- instrumental – the ability to assess the methodological approaches to carry out their critical analysis;
- interpersonal – ability to independently develop and deepen their knowledge and acquire new skills in a professional manner; knowledge of a foreign language in an amount sufficient to communicate freely in arbitrary topics;
- system – the ability to plan the steps of solving professional problems and implement them in time; demonstrate independence and original approach to problem solving, the ability to justify and make decisions.</td></tr>
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<table>
<tr><td>List of literature</td><td colspan="3">Main:

1. Eleuterio F. Toro Riemann Solvers and Numerical Methods for Fluid Dynamics A Practical Introduction //Springer Third Edition ISBN 978-3-540-25202-3.
2. John D. Anderson, Jr. Modern Compressible Flow // Second Edition. International Edition 1990.
3. Culbert B. Laney Computational Gasdynamics // Cambridge University Press 2007, P. 613.
4. T. J. Chung Computational Fluid Dynamics // Cambridge University Press 2002, P. 1012.
5. К. Флетчер Вычислительные методы в динамике жидкостей // Москва «Мир» 1991, Том 1,2. 502 с.

Additional:

1. C. Hirsch Numerical Computation of Internal and External Flows: The Fundamentals of Computational Fluid Dynamics // First published by John Wiley & Sons, Ltd, Second Edition 2007, P. 680.
2. Д. Андерсон, Дж. Таннехил, Р. Плетчер Вычислительная гидромеханика и теплообмен // Москва «Мир» 1990, Том 1, 2. 726 с.
</td></tr>
<tr><td>Organization</td><td colspan="3">Concept of the course is based on the book “Computational Gasdynamics (CGD)” by Culbert B. Laney. As a result of studying the course, students should know the basic system of equations for compressible flows, numerical methods of solution these equations, pros and cons of that numerical methods.</td></tr>
<tr><td>course Requirements</td><td colspan="3">All the assignments must be completed until due date. Students, who could not earn 50% out of 100% during first or second midterm and final, will be able to work off during an additional term. Late assignment is not accepted except for extenuating circumstances (e.g. field trip, hospitalization). Stu-dent, who failed to meet all kinds of work, is not allowed for passing an exam. In addition, the assess-ment takes into account the activity and attendance of students during class.

Be tolerant and respect other people's opinions. The objections should be formulated in a correct manner. Plagiarism and other forms of cheating are not allowed. Cheating is not accepted during inde-pendent work of student (IWS), midterm and final exam, copying solved problems from others, passing the exam to another student are not allowed also. Student convicted of falsifying any information about the course, any unauthorized upload to the “Intranet” using cheat sheets, will be graded with a final grade «F». For advice on the implementation of IWS, submitting and defending, as well as additional information on the studied material and all the other issues that arose upon studying the course, contact the instructor during his office hours.</td></tr>
<tr><td rowspan="3">evaluation Policy</td><td>Description self study results</td><td>Weigh t</td><td>Description self</td></tr>
<tr><td>Hometasks
Development of a database project
Programming Project
examinations
TOTAL</td><td>35%
10%
15%
<u>40%</u>
100%</td><td>1,2,34,5,6
2,3,4
4,5,6
1,2,3,4,5,6</td></tr>
<tr><td colspan="3">Your final score will be calculated by the formula below:

$$\text{Total score of the course} = \frac{PK1 + PK2}{2} \cdot 0{,}6 + 0{,}1ME + 0{,}3FE$$

Below are minimum estimates in percent:
95% - 100%: A   90% - 94%: A-
85% - 89%: B+   80% - 84%: B   75% - 79%: B-
70% - 74%: C+   65% - 69%: C   60% - 64%: C-
55% - 59%: D+   50% - 54%: D-   0% -49%: F</td></tr>
<tr><td></td><td colspan="3">Appropriate timing of homework or projects may be extended in the event of extenuating circumstances (such as illness, emergencies, emergency, contingency, etc.) in accordance with the University's academic policies. Student participation in discussions</td></tr>
</table>

discipline Policy	and exercises in the classroom will be taken into account in its overall assessment of the discipline. Design issues, dialogue and feedback on the subject matter of discipline are welcomed and encouraged in the classroom, and the teacher in the derivation of the final grade will take into account the participation of each student in the class.

Schedule discipline

Week	Title of the theme	Hour	Grade
1	**Lecture 1.** Compressible Flow – Some History and Introductory Thoughts **Lab.1.** Modern Compressible Flow. **IWM 1.** Aerodynamic forces on a body.	2 1	14
2	**Lecture 2.** Integral forms of the conservation equations for inviscid flows. **Lab.2.** Continuity and momentum equations. **IWM 2.** Energy equation.	2 1	14
3	**Lecture 3.** One-Dimensional Flow **Lab.3.** Speed of Sound and Mach Number. **IWM 3.** Hugoniot Equation.	2 1	14
4	**Lecture 4.** Conservation and other basic principles. **Lab.4.** The CFL condition. **IWM 4.** Upwind and adaptive stencils.	2 1	14
5	**Lecture 5.** Artificial viscosity. **Lab.5.** Linear stability. **IWM 5.** Nonlinear stability.	2 1	14
6	**Lecture 6.** Basic numerical methods for scalar conservation laws. **Lab.6.** Godunov's first-order upwind method. **IWM 6.** Roe's first-order upwind method.	2 1	14
7	**Lecture 7.** Beam-warming second-order upwind method. **Lab.7.** Harten's first-order upwind method. **IWM 7.** Test problem.	2 1	16
	1st control test	1	**100**
	Midterm exam	1	**100**
8	**Lecture 8.** Basic numerical methods for the Euler equations. **Lab.8.** Flux approach.	2 1	12

	IWM 8. Wave approach.		
9	**Lecture 9.** Boundary treatments. **Lab.9.** Second and higher order accurate methods. **IWM 9.** Test problem.	2 1	12
10	**Lecture 10.** Flux averaging I: flux-limited methods. **Lab.10.** Flux-limited TVD. **IWM 10.** Second and third order accurate methods.	2 1	12
11	**Lecture 11.** Flux averaging II: flux-corrected methods (FCT). **Lab.11.** Harten's FCT-TVD. **IWM 11.** Shu-Osher method ENO.	2 1	12
12	**Lecture 12.** Flux averaging III: self-adjusting hybrid methods. **Lab.12.** Harten's self-adjusting hybrid methods. **IWM 12.** Jameson's self-adjusting hybrid methods.	2 1	12
13	**Lecture 13.** Solution averaging: reconstruction-evolution methods. **Lab.13.** Van Leer's reconstruction evolution method MUSCL. **IWM 13.** Anderson –Thomas- Van Leer reconstruction evolution methods (TVD/MUSCL)	2 1	12
14	**Lecture 14.** Harten-Osher reconstruction-evolution method UNO **Lab.14.** Harten-Engquist-Osher-Chakravarthy reconstruction-evolution method ENO **IWM 14.** Third-order accurate temporal evolution for scalar conservation laws.	2 1	12
15	**Lecture 15.** WENO scheme. **Lab.15.** A brief introduction to multidimensions. **IWM 15.** Prepare a presentation.	2 1	16
	2nd control test	1	100
	Exam		**100**

Dean of the Faculty M.A. Bektemesov

Chairman of the Bureau of the method F.R. Gusmanova

Head of the department Z. Rakisheva

Lecturer Ye. Belyayev